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Knowledge Creation with Parallel Teams: Design of Incentives and the Role of Collaboration

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ABSTRACT

Parallel team strategy has been widely adopted by high-tech industries in knowledge creation. In this research, we study the design of organizational incentives, including a fixed wage payment and an additional reward structure, for the parallel team strategy. We consider two types of parallel teams—*collaborative* and *non-collaborative* parallel teams. Proposing and investigating two types of organizational reward policies (individual and aggregate) for both collaborative and non-collaborative parallel teams, we demonstrate the viability and characteristics of these policies and analyze the tradeoff between the number of parallel teams and their rewards. We show that collaboration in parallel teams is vital for obtaining maximal benefits. This research provides valuable insights for firms in employing parallel team strategy for knowledge creation.

Keywords

Collaboration, Incentives, Knowledge Creation, Parallel Team.

INTRODUCTION

Team has been considered as an effective organizational structure for all sorts of innovative activities. In a ground-breaking study of the practices of General Motors in 1943, Peter Drucker pointed out the effectiveness of team-based structures in organizations. As evidenced by numerous successful cases, team structures have been employed in many new projects. For example, Microsoft launched its brand-new gaming platform Xbox to compete with the popular PlayStaion 2 from Sony, within a short period of time by employing the team strategy. At Google, various teams are assembled to work on different projects, such as Google Documents, Google Health, and Google Checkout.

There are many insightful perspectives on team composition. Drucker (1998) identifies three kinds of team as the baseball team, the football team, and tennis doubles team. Cohen and Bailey (1997) categorize teams in organizations into four types: work teams, parallel teams, project teams, and management teams. Katzenback and Smith (2005) suggest three types of teams: teams that recommend things, teams that make or do things, and teams that run things. Although they seem disparate, these papers shares similar notions on teams. For instance, a parallel team categorized by Cohen and Bailey (1997) is the same as a football team identified by Drucker (1998).

Due to the increasingly complex nature of technologies, not only do firms have to adopt appropriate team structures, but also assemble multiple teams to collectively engage in a single R&D project. For instance, more than 200 programmers were involved at Microsoft to develop Windows 95 that contains more than 11 million lines of code (Cusumano and Selby, 1997). Therefore, firms are continuously seeking cost-effective strategies to manage and coordinate teams on innovative projects.

Different team strategies have been employed by industries for innovation and research. Concurrent team strategy has been widely adopted to shorten the development time of new products. For instance, project managers at Microsoft usually divide a project into parts with respect to its features. Teams then work simultaneously on their parts but they synchronize with each other and debug daily (Cusumano, 1997). In contrast, with the parallel team strategy, all teams work on a same research project simultaneously so as to maximize the overall success rate of the project. Parallel team strategy is frequently applied in research where single-team strategy results in extremely high failure rates. For example, Nelson (1961) documents the adoption of parallel-path strategy in R&D by U.S. Air force. Similar parallel-path strategy was also recently used at National Institute of Health(NIH) to develop malaria vaccine. In contrast, in the traditional process of malaria vaccine development, when one approach failed, the effort died with it as well (Seiguer, 2002). In this paper, we study how the parallel team strategy can be employed in knowledge creation. In particular, how should a firm choose the optimal number of teams to work on research simultaneously and how to reward the teams?

There exists a plethora of research on teams in economics, organizational science, and IS literature. Classical principal-agent models explore the optimal incentive structure under incomplete information and the relationship between first best and second best solutions (Holmstrom, 1979; Grossman and Hart, 1983; Spence, 1973). Theory of teams (Marshak and Radner, 1972) requires different incentive systems (Groves, 1973; Holmstrom, 1982; McAfee and McMillan, 1991). Knowledge creation in firms follows dynamic processes (Nonaka, 1994) with different strategies (Liebeskind, 1996). However, only a few studies have analyzed the economic implications of parallel team strategies (Arditti and Levy, 1980; Dutta and Prasad, 1996). Besides, these studies do not discuss how to design necessary incentives to increase the success rate of a research project in conjunction with the optimal number of teams. In addition, the collaboration in teams that affects the success rate of innovation has never been modeled before. Our research bridges this gap by analyzing the critical role of collaboration and incentives for applying the parallel team strategy. Specifically, we address the following research questions in this paper.

First, *how does the optimal number of teams and reward policies differ between collaborative and non-collaborative parallel teams?* Multiple parallel teams can be formed as either non-collaborative or collaborative parallel teams similar to the differentiation between working groups and teams by Katzenback and Smith (2003): non-collaborative teams is loosely bounded together for some common goals, whereas collaborative teams coalesce because of the collaboration among them. In particular, non-collaborative teams work independently without learning from or sharing with other teams, whereas collaborative teams work closely together so as to effectively increase the success rate of the research project. We study whether and how the presence of collaboration in parallel teams helps a firm to design better incentive contracts to achieve maximal benefits.

Second, *how should a firm design incentive contracts for parallel research teams to induce them to exert their best efforts?* The incentive contracts for a team in this research consist of a fixed wage payment and an additional reward policy. All the teams get the fixed payment no matter whether they will succeed in research and they will be rewarded additionally if their research project succeeds. Two types of reward policies (individual and aggregate) are proposed in this paper and analyzed as to how these rewards should be designed to induce the best efforts from teams so that the firm may achieve maximal profit.

Finally, *how many parallel teams should a firm employ for knowledge creation?* Prior research studied the optimal number of parallel teams, but without the incentive issues. This research makes the significant extension by investigating the optimal number of parallel teams while taking into account the incentives to motivate the best efforts.

The paper proceeds as follows. §2 outlines our model. §3 presents the detailed analysis and discussion. §4 provides managerial insights and concludes the paper.

MODEL

In this section, we present a model in which a firm designs optimal incentives for parallel team strategy. Beginning with the individual team's decision problem under the individual team reward policy, we then show the organizational decision problem. Finally, we derive a simplified model for analysis.

We consider a firm that wishes to employ multiple parallel teams to engage in a research project for knowledge creation. Each team, acting independently, exerts a certain level of effort, generating a success rate for the research project. In our model, the team is considered a unit of analysis. The specifics of how the collective effort is distributed within the team and how the team is composed of are discussed in a different research paper. In addition, we assume all the teams are homogeneous with respect to their abilities in research.

The firm chooses M number of parallel teams and offers a payment structure that consists of two parts: a fixed wage payment w and an additional reward r. The payment for individual team reward policy can be modeled as

$$\text{individual policy} = \begin{cases} w & \text{unsuccessful teams,} \\ w + r & \text{successful teams.} \end{cases}$$

Under the individual policy, a team i 's expected net payoff is

$$\pi_i = w - c(e_i) + \rho^I(e_i, M) \cdot r, \tag{1}$$

where e_i is its effort exerted , $c(e_i)$ is the cost of effort, and $\rho^I(e_i, M)$ is the individual team's probability of success rate which will be discussed in details later on.

Accordingly, the firm's net payoff is

$$\pi = \rho^G(E, M)B - M \cdot w - \sum_{i}^{M} \rho^I(e_i, M) \cdot r, \tag{2}$$

in which E is a vector containing all parallel teams' efforts, B is the benefit of the research project, and $\rho^G(E, M)$ is the group success rate of all the teams.

Parameters	
B	benefit of research
$\rho^I(\cdot)$	individual team success rate
$\rho^G(\cdot)$	group success rate of all teams
U_r	reservation utility
Decision Variables	
e	team effort
M	number of teams
r	individual team reward
R	aggregate team reward
w	fixed wage payment

Table 1. Summary of Notation

Formally, the firm's problem $[P]$ can be defined as

$$\max_{w,M,r} \ \pi, \tag{3}$$

subject to

$$E \in \text{Equilibrium set } E^*,$$
$$\pi_p \geq U_r,$$
$$w \geq 0,$$

where the first constraint is the incentive-compatibility constraint (IC) for teams in which E^* is the equilibrium set of effort among M teams, the second constraint is the individual-rationality constraint (IR) in which U_r is the reservation utility, and the last one is to ensure a positive wage payment (see Table 1 for the complete list of notations). When the aggregate reward policy is applied, all the teams will equally share an aggregate reward R when the research succeeds; the individual team's payoff and firm's profit can be formulated accordingly.

We conduct our analysis in the next section for different scenarios: (1) for non-collaborative and collaborative parallel teams; (2) for individual or aggregate team reward policy.

For a team in a non-collaborative setup, individual team success rate does not correlate with the total number of teams. Hence, the individual team success rate can be defined as $\rho^I(e, M) = \rho(e)$, which is independent of the total number of teams M. Then the group team success rate is just $\rho^G(e, M) = 1-(1-\rho^I(e, M))^M = 1-(1-\rho(e))^M$. It is assumed that $\rho''(e)(1-\rho(e)) + [\rho'(e)]^2 \leq 0$.

For a team in a collaborative setup, individual team success rate depends on the total number of teams. Due to the collaboration among all the parallel teams, individual team success rate may increase when more teams engage in research. In this regard, we define the individual team success rate as $\rho^I(e,M)=1-(1-\rho(e))^{\frac{q(M)}{M}}$, then the group team success rate will be $\rho^G(e,M)=1-(1-\rho^I(e,M))^M=1-(1-\rho(e))^{q(M)}$, where $q(M)$ measures the degree of collaboration among M teams. When $q(M)=M$, there is no collaboration among teams, which is the same as the above case for a group of teams. When $q(M)>M$, there is collaboration among teams, which helps to improve individual team success rate $\rho^I(e,M)$. When $q(M)<M$,the total number of teams will have opposite and negative effect on individual team success rate, which eventually reduces individual team success rate $\rho^I(e,M)$. In general, we assume that $q(M)$ is a concave function, first increasing then decreasing in M with the properties that $q(0)=0$ and $q(1)=1$.

We next introduce two lemmas, which greatly simplifies the firm's problem.

Lemma 1. *There always exists a unique symmetric equilibrium of teams' effort levels when the individual reward policy is applied.*
Proof. Please see Appendix A.

Lemma 2. The *individual-rationality constraints are always binding for each team*.
Proof. Please see Appendix B.

Following upon Lemma 1, we simplify the notation e_i as e for all the individual team effort levels under the individual reward policy and the incentive-compatibility constraint is thus reduced into

$$e \in \underset{\tilde{e}}{argmax}\{w-c(\tilde{e})+\rho^I(\tilde{e},M)r\}.$$

Lemma 2 lets us further reduce the firm's problem with individual reward policy into

$$\max_{(r,M)} \ \pi=-M[c(e)+U_r]+\rho^G(e,M)B$$

subject to

$$e \in \{\tilde{e} \mid c'(\tilde{e})=\rho^I_{\tilde{e}}(\tilde{e},M)r\},$$

$$c(e)-\rho^I(e,M)r+U_r \geq 0.$$

ANALYSIS AND DISCUSSION

This section details our analysis on parallel teams. First, we discuss the optimal solution for non-collaborative teams with individual reward policy. Second, we explore various conditions focusing on the team elasticity of collaboration for collaborative teams. Finally, the impacts of aggregate team reward policy are investigated on the equilibria of teams' effort levels.

Non-collaborative teams

For non-collaborative teams, we show in the next proposition that the firm can only achieve the second-best solution by not offering any fixed wage payments to teams because of the lack of collaboration in teams.

Proposition 1. *The firm cannot achieve the first-best solution for non-collaborative teams and the second-best reward and optimal effort level can be determined from*

$$r = \frac{c'(e)}{\rho'(e)}$$

$$U_r = \frac{\rho(e)}{\rho'(e)} c'(e) - c(e).$$

Proof. Please see Appendix C.

The reason that the first-best solution cannot be achieved in non-collaborative teams lies in the contradiction that the firm cannot obtain a positive profit while maintaining a positive wage payment. Figure 1 explains this intuition by showing individual team's iso-utility wage contours and the firm's indifference curve when there is no collaboration in parallel teams.

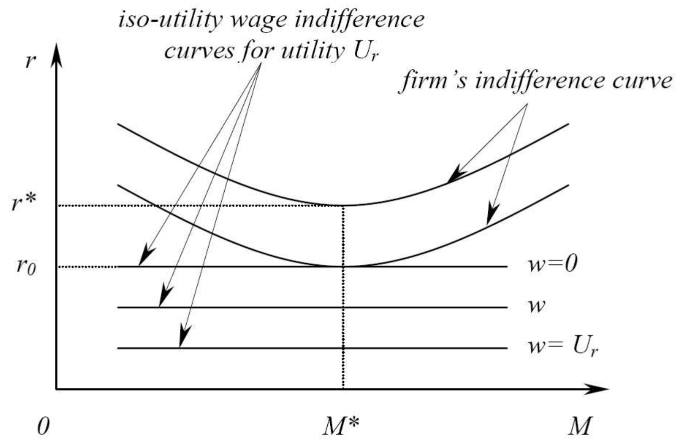

Figure 1. Team's iso-utility wage contours and firm's indifference curve: no collaboration

Since individual team's effort level is solely determined by $c'(e)/\rho'(e) = r$, which is not related to the number of teams M. Then, $dr/dM = 0$, which implies that iso-utility wage contours are horizontal lines. Figure 1 shows these lines for the reservation utility U_r. The firm's substitution rate is

$$\frac{dr}{dM} = -\frac{\frac{\partial\pi}{\partial M}}{\frac{\partial\pi}{\partial r}} = -\frac{\rho_M^G B - w - \rho(e)r + (\rho_e^G B - M\rho'(e)r)\frac{\partial e}{\partial M}}{(\rho_e^G B - M\rho'(e)r)\frac{\partial e}{\partial r} - M\rho(e)},$$

which is zero at point (M^*, r^*) that satisfies the following two conditions

$$\rho_M^G B = w + \rho(e)r = c(e) + U_r,$$

$$\rho_e^G B = M\rho'(e)r = Mc'(e).$$

These two conditions suggest that the optimal effort level e^* is characterized by

$$\frac{c'(e^*)}{\rho'(e^*)} = \frac{c(e^*) + U_r}{-(1-\rho'(e^*))ln(1-\rho'(e^*))}.$$

When the wage payment is zero, individual team's effort level can be obtained from

$$\frac{c'(e_0)}{\rho'(e_0)} = \frac{c(e_0) + U_r}{\rho(e_0)}.$$

Since $-(1-\rho'(e))ln(1-\rho'(e)) < \rho(e), \forall e > 0$, it follows that $e^* > e_0$, or $r^* > r_0$, which implies that the firm's indifference curve for maximal profit can never intersect with individual team's iso-utility wage contours for utility U_r. Therefore, the firm can only achieve the second-best solution by lowering r^* to r_0, offering zero wage payment to individual teams. M^* remains unchanged in both first-best and second-best cases. In summary, in a group of teams, the firm cannot achieve the first-best effort levels from teams. The second-best effort levels can be obtained by paying teams a proportion of the research benefit under certain conditions.

Collaborative Teams

Having illustrated the firm's second-best solution to a group of teams, we next turn our attention to the incentive design and the optimal number for collaborative teams.

Individual reward policy

In this section, we demonstrate that for collaborative teams, the firm may achieve a first-best solution under some conditions (see Appendix D for the lagrangian function of the firm's profit). We first define and investigate the complementarity between the effort level e and the total number M of teams, then propose the concept of team elasticity of collaboration, and finally characterize the conditions to obtain the first-best and second-best solutions.

The complementarity is defined as the relation between the effort level and the number of teams with respect to their contribution to the firm's total expected profit. If $\partial^2\pi/\partial e\partial M = 0$, there exists no complementarity between e and M, which means that the effort level is independent of the total number of teams; if $\partial^2\pi/\partial e\partial M > 0$, there exists positive complementarity between e and M, implying that the effort level increases when there are more teams; and if $\partial^2\pi/\partial e\partial M = 0$, there exists negative complementarity between e and M so that the effort level decreases when more teams work in parallel. The next lemma shows the sufficient condition for the Hessian matrix of the firm's profit to be negative definite, leading to the further discussion on the complementarity between e and M.

Lemma 3. The sufficient condition for the Hessian matrix of the firm's profit to be negative definite with collaborative teams is that the following inequality holds at the stationary point (e^*, M^*)

$$-q'(M)q(M)ln(1-\rho(e)) \geq \left| q'(M)[1+q(M)ln(1-\rho(e))] - \frac{q(M)}{M} \right|. \tag{4}$$

Proof. Please see Appendix E.

Based on the above lemma, we first consider the case when $1+q(M)ln(1-\rho(e)) \leq 0$. As proved in Appendix E, there always exists negative complementarity for this case between e and M and the above inequality (4) can be simplified as

$$\frac{q(M)}{q'(M)M} \leq 1.$$

Secondly, when $1+q(M)ln(1-\rho(e)) > 0$, if

$$[1+2q(M)ln(1-\rho(e))] \leq \frac{q(M)}{q'(M)M} < [1+q(M)ln(1-\rho(e))], \tag{5}$$

there exists *positive complementarity* between e and M, and if

$$[1+q(M)ln(1-\rho(e))] < \frac{q(M)}{q'(M)M} \leq 1, \tag{6}$$

there exists *negative complementarity* between e and M.

Finally, when there is no complementarity between the effort level e and team size M, the Hessian matrix is always negative definite. In addition, the following equation always holds

$$\frac{dM}{M} = \frac{dq(M)}{q(M)}[1+q(M)ln(1-\rho(e))].$$

Since $q(1)=1$, the relationship between the optimal effort level e^* and the number of teams M^* can be solved as

$$M^* = q(M^*)(1-\rho(e^*))^{q(M^*)-1}. \quad (7)$$

We define the term

$$\psi = \frac{Mq'(M)}{q(M)}$$

as the team elasticity of collaboration which measures how the degree of collaboration changes when there is one more team in the collaborative structure. Notice that this team elasticity can be negative if the collaboration strength starts to decrease when more teams are in the group. The conditions for the stationary point (e^*, M^*) to achieve either positive, zero, or negative complementarity are summarized in Table 2.

Types	**Team elasticity of collaboration** $\psi = \frac{Mq'(M)}{q(M)}$
positive complementarity	$1 < \psi \leq \frac{1}{1+2ln(1-\rho^G)}$
zero complementarity	$\psi = \frac{1}{1+ln(1-\rho^G)} \Rightarrow M^* = q(M^*)(1-\rho(e^*))^{q(M^*)-1}$
negative complementarity	$1 \leq \psi < \frac{1}{1+ln(1-\rho^G)}$ when $\rho^G \in [0, 0.632)$ and $\psi \geq 1$ when $\rho^G \in [0.632, 1]$

Table 2. Complementarity conditions regarding the team elasticity of collaboration

Having discussed the complementarity between e and M with respect to team elasticity of collaboration ψ, we next demonstrate the conditions for the firm to achieve a first-best solution.

Proposition 2. *Under individual reward policy, the necessary and sufficient condition for both the firm's optimal profit and the fixed wage payment to be positive is*

$$\frac{M\rho^I}{-(1-\rho^I)ln(1-\rho^G)} \leq \frac{q'(M)M}{q(M)} \leq \frac{\rho^G}{-(1-\rho^G)ln(1-\rho^G)},$$

and the teams' optimal effort level can be characterized as

$$\frac{c'(e^*)}{\rho'(e^*)} = \frac{q(M^*)}{M^*}(1-\rho(e^*))^{q(M^*)-1}B,$$

which can be induced by offering the optimal reward as

$$r^* = \frac{c'(e^*)}{\rho_e^I(e^*, M^*)} = \frac{(1-\rho(e^*))^{q(M^*)}}{(1-\rho(e^*))^{\frac{q(M^*)}{M^*}}}B.$$

Proof. Please see Appendix F.

Proposition 2 demonstrates the conditions for the firm to obtain the first-best solution, which enables the firm to offer a positive fixed wage payment and still maintain a positive optimal profit. The condition essentially implies that under the individual reward policy, the necessary condition for both a firm's optimal profit and the fixed wage payment to be positive is the existence of negative complementarity between e and M. In other words, when the firm achieves the first-best solution, there should always exist the negative complementarity between the group size and effort level, i.e., when more teams join in the group, each team exerts less effort.

When the conditions of obtaining the first-best solution cannot be satisfied, the firm may still achieve the second-best solution under certain condition, which is presented in the next proposition.

Proposition 3. *Under the individual reward policy, the firm can only achieve the second-best solution by paying a zero wage payment if*

$$\frac{Mq'(M)}{q(M)} < \frac{M\rho^I}{-(1-\rho^I)ln(1-\rho^G)},$$

and the effort level and reward in this case can be determined from

$$r = \frac{c'(e)}{\rho_e^I(e,M)},$$

$$c(e) = \rho^I(e,M)r - U_r.$$

Proof. Please see Appendix G.

Figure 2 demonstrates the iso-utility wage contours for teams between reward and the number of teams. In particular, for a fixed wage payment w to achieve certain utility, there can be various combinations between r and M, that is,

$$\frac{dr}{dM} = -\frac{\frac{\partial w}{\partial M}}{\frac{\partial w}{\partial r}} = -\frac{\rho_M^{I_i}}{\rho^{I_i}} r < 0,$$

and $d^2r/dM^2 > 0$. Hence, the substitution rate between r and M for a fixed wage monotonically decrease.

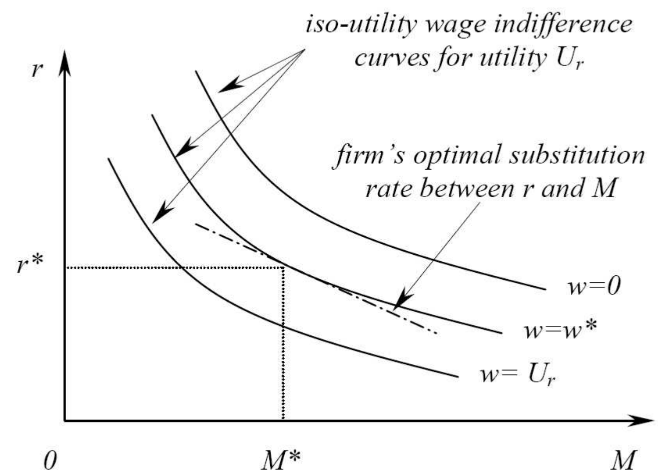

Figure 2. Team's iso-utility indifference curves for a fixed wage: first best

The firm's marginal indifference rate between r and M for a fixed profit is

$$\frac{dr}{dM} = -\frac{\frac{\partial \pi}{\partial M}}{\frac{\partial \pi}{\partial r}} = -\frac{\rho_M^G B - w - \rho^I r - M\rho_M^I r + (\rho_e^G B - M\rho_e^I r)\frac{\partial e}{\partial M}}{(\rho_e^G B - M\rho_e^I r)\frac{\partial e}{lr} - M\rho^I},$$

which will equal individual's substitution rate at the point (M^*, r^*) that satisfies conditions

$$\rho_M^G B = w + \rho^I r = c(e) + U_r,$$

$$\rho_e^G B = M\rho_e^I r = Mc'(e).$$

These two conditions are essentially the first-order conditions of the firm's profit with respect to e and M. If the optimal point (M^*, r^*) is within the region for team's iso-utility contours with utility U_r, as shown in Figure 2, then the first best solution can be achieved. However, if the optimal point (M^*, r^*) is out of the region for team's iso-utility wage contours with utility U_r as shown in Figure 3, the firm has to move its indifference curve downward such that it is tangent with team's iso-utility wage contour at $w = 0$. In this case, the firm has to bind team's positive wage constraint and achieve a positive second-best profit.

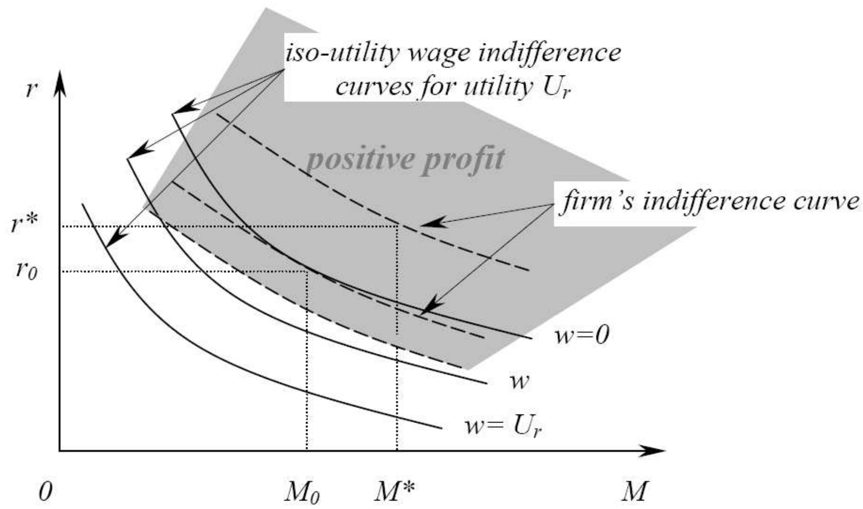

Figure 3. Team's iso-utility wage contours and firm's indifference curve: second best

Aggregate reward policy

Instead of offering rewards to successful individual teams, the firm can equally reward *all* the teams when the research succeeds. We first demonstrate a similar symmetric equilibrium as that under individual reward policy. Under the aggregate reward policy, asymmetric equilibrium may exist where teams exert efforts at different levels. However, we finally demonstrate that only the symmetric equilibrium exist as long as all the teams in sub-teams collaborate as one team.

If the firm employs aggregate reward policy for its parallel collaborative teams, similar symmetric equilibrium may exist as that under the individual reward policy. The next proposition shows that no such conditions exist for the firm to both offer a positive wage payment and achieve a positive profit.

Proposition 4. *Under the symmetric equilibrium of aggregate reward policy, the necessary and sufficient condition for* $w^* \geq 0$ *(or, for the firm to be able to offer a positive fixed wage payment) is*

$$\frac{q'(M)M}{q(M)} \geq \frac{M\rho^G}{-(1-\rho^G)ln(1-\rho^G)},$$

and the necessary and sufficient condition for the firm's optimal profit to be positive is

$$\frac{q'(M)M}{q(M)} \leq \frac{\rho^G}{-(1-\rho^G)ln(1-\rho^G)},$$

and the effort level and aggregate reward in this case can be determined from

$$\frac{R}{M} = \frac{c'(e)}{\rho_e^G(e,M)},$$

$$c(e) = \rho^G(e,M)\frac{R}{M} - U_r.$$

Proof. Please see Appendix H.

Proposition 4 illustrates that it is impossible for the team elasticity of collaboration to satisfy both conditions as those for individual team reward policy. Hence, the firm cannot achieve a positive profit and offer a positive wage payment at the same time under the symmetric equilibrium of aggregate reward policy. Therefore, to achieve a positive profit under the symmetric equilibrium of aggregate reward policy, the firm should not offer a fixed wage payment to teams.

We next investigate the possible asymmetric equilibrium when there exist two or more sub-teams among parallel teams. We show that the optimal solution requires the firm to induce teams to exert efforts at the same level no matter how many sub-teams may exist.

Proposition 5. *The asymmetric equilibrium does not exist when the firm offers the aggregate reward and all parallel teams collaborate as one team.*
Proof. Please see Appendix I.

Proposition 5 implies that all the teams exert same effort levels as long as they enjoy the collaboration among all the participants. The solution in this case is the same as that under the symmetric equilibrium. If there hardly exists any collaboration among the sub-teams, then the group success rate will be different and there may exist asymmetric equilibrium among teams.

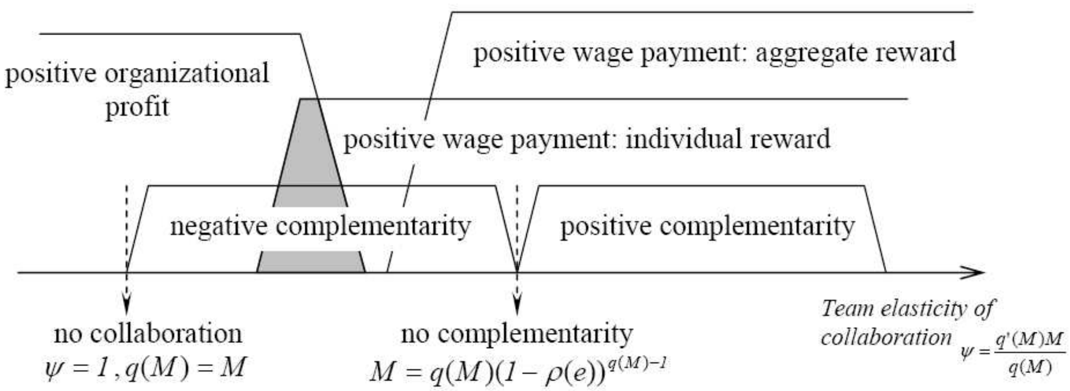

Figure 4. Various conditions with respect to team elasticity of collaboration ψ

Figure 4 graphically summarizes our findings about two types of reward policies with regard to the team elasticity of collaboration. According to our conditions in previous propositions, different areas are identified with respect to the team elasticity of collaboration. In addition, we add in collaboration and complementarity to the chart so that their relationship to the firm's decision can be easily seen. Since there lacks collaboration in non-collaborative teams, the team elasticity of collaboration is 1 and the firm can achieve a positive profit, but cannot offer a positive wage payment to teams. When there exists no complementarity between team effort levels and the number of teams, it is possible to offer a positive wage payment to teams under both types of reward policies; however, the firm will not be able to achieve a positive profit under such situation. The shaded area represents the range of team elasticity of collaboration that enables the firm to achieve the first-best solution, both the firm's optimal solution and the fixed wage payment are positive. Figure 4 also presents the comparison between individual and aggregate reward policy: the first-best solution may be obtained when the team elasticity of collaboration is within a certain range under individual reward policy, but only second-best solution can be achieved under aggregate reward policy.

MANAGERIAL IMPLICATIONS AND CONCLUSION

The increasingly competitive market has forced companies to seek more cost-effective ways to engage in knowledge creation. The recent trend in outsourcing knowledge clearly indicates that companies are constantly searching for the best business strategy to not only save the costs but also improve the quality of knowledge discoveries.

To derive important managerial insights about how to effectively employ parallel team strategies, we presented a model of parallel teams and incentives in which a firm employs multiple teams and designs incentives to motivate these teams to exert their best efforts. Our analysis provides valuable guidance for managers in deploying parallel teams as discussed below. First, motivating teams to effectively engage in knowledge creation is essential for firms to improve their productivity and overall performance. We show how appropriate incentives can be designed. Appropriate incentives (for instance, wage payments) can be designed to induce workers' best efforts in knowledge innovation, enhancing the success rate of knowledge discovery.

Second, collaboration is indispensable within parallel teams for knowledge creation to achieving maximal benefits. In non-collaboration teams, the firm should not offer any fixed payment to a group of teams, but only offer the reward part that shares the knowledge creation benefit, since only the second-best solution is attainable.

Third, successful innovation teams can be rewarded either individually or collectively. Although it is possible to achieve the first-best effort levels with the individual team reward policy, the incentive to motivate collaboration may not be so strong because only successful teams get the reward. In contrast, under the aggregate reward policy, teams will share the total reward as long as any team succeeds, so they may be induced to voluntarily collaborate with other teams.

This study sheds light on how incentives and collaboration among teams affect organizational decisions on knowledge creation. We plan to study the uncertainty of innovation benefit with potential knowledge discovery and investigate the impacts of information technology in more detail. In conclusion, our paper provides valuable insights for managers to choose the best number of parallel teams for knowledge discovery and also determine appropriate level of rewards to achieve optimal organizational profits.

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APPENDIX

Appendix is omitted due to lack of space and is available at http://faculty.plattsburgh.edu/justin.zhang/Appendix_AMCIS2009.pdf.